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REVIEW

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Should dietary guidelines recommend low red meat intake?

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ABSTRACT
Mainstream dietary recommendations now commonly advise people to minimize the intake of red meat for health and environmental reasons. Most recently, a major report issued by the EAT-Lancet Commission recommended a planetary reference diet mostly based on plants and with no or very low (14 g/d) consumption of red meat. We argue that claims about the health dangers of red meat are not only improbable in the light of our evolutionary history, they are far from being supported by robust scientific evidence.

KEYWORDS
red meat; health; vegetarianism; veganism; dietary guidelines; disease

1. Introduction

On January 16th, 2019, the EAT-Lancet Commission formally expressed its desire for a *Great Food Transformation* toward a predominantly plant-based diet for the planet (Willett et al., 2019). The proposed reference diet includes minute daily doses of beef (7 g), pork (7 g), and eggs (13 g), with somewhat larger amounts of poultry (29 g) and fish (28 g). Despite heavy restrictions on other animal source foods, it allows for 250 g of dairy products per day, with a limit of 153 kcal. Stricter vegetarian and even vegan diets were sanctioned as valid options too, provided that vitamin B12 supplements are taken in the case of veganism. In the words of the Commission: "This healthy reference diet …includes a low to moderate amount of seafood and poultry, and includes no or a low quantity of red meat, processed meat" (Willett et al., 2019). One of the "key messages" is that "Healthy diets…consist of a diversity of plant-based foods, low amounts of animal source foods." Red meat is specifically labeled as an "unhealthy food". While the authors acknowledge that livestock products can offer benefits for those who are nutritionally deficient, a strong reduction of animal products was said to be beneficial for both health and the environment. Soon after the release of this EAT-Lancet report, a similar argument was made by yet another Lancet Commission, classifying meat as a driver of the *Global Syndemic*—a system of interconnected global crises related to health and the environment—and arguing for an interventionist approach through mass-marketing campaigns and legal measures, including the mandatory use of warning labels and the application of taxes (Swinburn et al., 2019). Previously, other groups associated with the EAT-Lancet Commission have made similar recommendations. A study whose first author belongs to the EAT-Lancet Commission recently called for taxes on meat consumption (Springmann et al., 2018). The World Research Institute, a direct partner of the EAT-Lancet network, considers various interventions to reduce meat eating with varying degrees of compulsion (*e.g.*, influencing nutritional labeling and dietary guidelines, stimulating 30-day diet challenges, imposing taxes, and banning meat from menus) (Ranganathan et al., 2016).

Contemporary arguments against meat eating appeal mostly to nutritional, environmental, and ethical considerations (Leroy, 2019). The present review focuses on nutrition. Although the environmental and ethical arguments should certainly not be overlooked, these require separate analyses. Furthermore, the nutritional debate has its own complexities and controversies, for instance with respect to the potential health implications of shifts in macronutrient ratios toward elevated levels of carbohydrates (*e.g.*, Deghan et al., 2017) or the reliance on ample amounts of cereals (*e.g.*, Antvorskov et al., 2018), soy (*e.g.*, Siepmann et al., 2011), and plant oils (*e.g.*, DiNicolantonio, 2014). The present overview, therefore, will be dedicated to the specific topic of severe meat restriction or avoidance and the potential impact of such dietary restriction on health. Ultimately, the conclusions will have to be integrated into a more holistic evaluation that balances nutrition, sustainability, and ethics.

2. Meat and health: a shifting paradigm?

Humans are biologically adapted to a diet that includes meat. Archeological findings suggest that hominins were butchering animals with stone tools 2.5 million years ago (de Heinzelin et al., 1999). At some point we lost the ability to absorb vitamin B12 in the large intestine, where it is produced by gut bacteria, making man dependent on dietary sources of the vitamin (Schjønsby, 1989). Presumably our ancestors were able to survive losing this ability because

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they were regularly consuming B12-rich meat (Lents, 2018). Hominin skeletal remains from 1.5 million years ago show signs of porotic hyperostosis, which is generally linked to B12 deficiency and is virtually absent in chimpanzees who still obtain B12 from gut bacteria (Domínguez-Rodrigo et al., 2012). This provides some evidence that "by at least the early Pleistocene meat had become so essential to proper hominin functioning that its paucity or lack led to deleterious pathological conditions" (Domínguez-Rodrigo et al., 2012). Over time our capacity to convert the omega-3 fatty acid alpha-linolenic acid (ALA), found in plants, to the biologically important eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) forms (found primarily in seafood, but also in meat, eggs, and dairy; Tur et al., 2012) became greatly reduced in comparison to other primates (Stark et al., 2016). The shift to energy-dense meat caused our guts, particularly our large intestines, to shrink significantly compared to those of apes. Gut proportions in humans are also adapted to meat eating. Our small intestine (in which most nutrients are extracted) comprises 56% of total gut volume, while the large intestine comprises about 20%—these proportions are reversed in apes (Milton, 2003). Meat eating, and the concomitant reduction in size of the energy-consuming gut, is believed to have played an essential role in the increase of brain size in the hominin lineage. Because the brain and gut compete for energy, the former was able to increase in size when the latter became smaller (Aiello & Wheeler, 1995). Gupta (2016) expounds: "To build and maintain a more complex brain, our ancestors used ingredients found primarily in meat, including iron, zinc, vitamin B12 and fatty acids. Although plants contain many of the same nutrients, they occur in lower quantities and often in a form that humans cannot readily use."

The fact that we are biologically adapted to diets that include substantial amounts of meat does not by itself prove that low-meat diets cannot be healthy. However, when it comes to virtually every other species, we generally take it for granted that it will flourish best on a diet that roughly resembles the one to which it was adapted. It would be, though not impossible, somewhat *surprising* if *Homo sapiens* turned out to be such a spectacular exception to this principle. Nevertheless, mainstream nutrition discourse often portrays meat as a health disaster (see Leroy, 2019), suggesting that it can be readily replaced with legumes and B12 supplements, and whereby additional confusion is generated by sensationalist misrepresentations of the scientific evidence in mass media (Leroy et al., 2018a). Nonetheless, the anti-meat discourse is able to refer to a large set of international and peer-reviewed scientific data that have been institutionalized in dietary advice from various health authorities worldwide (*e.g.*, WHO, 2015; NHS, 2018). These data are, for the largest part, generated from observational studies within the domain of nutritional epidemiology, the limitations of which will be discussed below. Taken together, it is repeatedly stated in academic literature that high meat intake is associated with higher mortality (Sinha et al., 2009; Pan et al., 2012; Larsson & Orsini, 2014; Etemadi et al., 2017), cardiometabolic illnesses (Pan et al., 2011; Chen et al., 2013; Feskens et al., 2013; Abete et al., 2014; Yang et al., 2016; Kim & Je, 2018), diverse types of cancer (Huang et al., 2013; Farvid et al., 2015; Carr et al., 2016), and intestinal disorders (Cao et al., 2018). The above-mentioned Lancet reports (Swinburn et al., 2019; Willett et al., 2019) make recommendations based on this research, assuming causal relationships between meat intake and morbidity and mortality.

3. Meat eating and chronic disease: evaluation of the evidence

3.1. Evidence from observational studies needs to be interpreted with care

Despite the merits of epidemiology as a scientific discipline, an overwhelming corpus of often non-robust and overstated observational findings has been amassing over the last decades in the field of nutrition (Ioannidis, 2018). Naïve interpretations of these findings are often promoted by the media and influence nutritional guidelines. Ioannidis illustrates the absurdity of taking them at face value:

> Assuming the meta-analyzed evidence from cohort studies represents life span-long causal associations, for a baseline life expectancy of 80 years, eating 12 hazelnuts daily (1 oz) would prolong life by 12 years (i.e., 1 year per hazelnut), drinking 3 cups of coffee daily would achieve a similar gain of 12 extra years, and eating a single mandarin orange daily (80 g) would add 5 years of life. Conversely, consuming 1 egg daily would reduce life expectancy by 6 years, and eating 2 slices of bacon (30 g) daily would shorten life by a decade, an effect worse than smoking. (Ioannidis, 2018)

Schoenfeld and Ioannidis (2013) found that, among 50 common ingredients used in a cookbook, 40 had been associated with cancer risk or benefit based on observational studies.

As a first point of concern, the input data obtained from food frequency questionnaires should be interpreted prudently as they can be problematic for a variety of reasons (Schatzkin et al., 2003; Archer et al., 2018; Feinman, 2018). Social desirability bias in food reporting is just one example, as reported consumption can be affected by the perceived health status of certain foods. Not all self-defined vegetarians avoid meat, which is suggestive of a considerable risk for underreported intake in health-conscious groups (Haddad & Tanzman, 2003).

Secondly, diets are difficult to disentangle from other lifestyle factors. It has been shown that Western-style meat eating is closely associated with nutrient-poor diets, obesity, smoking, and limited physical activity (Alexander et al., 2015; Fogelholm et al., 2015; Grosso et al., 2017; Turner & Lloyd, 2017). Given the fact that health authorities have been intensely promoting the view that meat is unhealthy, health-conscious people may be inclined to reduce intake. Typically, the associations between meat eating and disease tend to be higher in North American than in European or Asian cohort studies, indicating the presence of lifestyle bias and the need for cross-cultural assessments (Wang et al., 2016; Grosso et al., 2017; Hur et al., 2018). A pooled analysis of prospective cohort studies in Asian countries even indicated that red meat intake was associated with lower cardiovascular mortality in men and cancer mortality in women (Lee et al., 2013). Likewise, when omitting Seventh-Day Adventist studies from meta-analyses, the beneficial associations with cardiovascular health for vegetarian diets are either less pronounced or absent indicating the specific effects of health-conscious lifestyle rather than low meat consumption as such (Kwok et al., 2014; FCN, 2018). This is important, as Seventh-Day Adventism has had considerable influence on dietary advice worldwide (Banta et al., 2018).

As a third point, the relative risks (RRs) obtained from observational studies are generally low, *i.e.*, much below 2. In view of the profusion of false-positive findings and the large uncertainty and bias in the data due to the problems mentioned above (Boffetta et al., 2008; Young & Karr, 2011), such low RR levels in isolation would not be treated as strong evidence in most epidemiological research outside nutrition (Shapiro, 2004; Klurfeld, 2015). Relationships with RRs below 2, which are susceptible to confounding, can be indicative but should always be validated by other means, such as randomized controlled trials (RCTs) (Gerstein et al., 2019). The association between meat eating and colorectal cancer, for instance, leads to an RR estimate below 1.2, whereas for the association between visceral fat and colorectal neoplasia this value equals 5.9 (Yamamoto et al., 2010). The latter provides a robust case that is much more deserving of priority treatment in health policy development.

To sum up, the case propagated by the EAT-Lancet Commission (Willett et al., 2019) has essentially been based on observational studies with RRs much below 2 (*e.g.*, Sinha et al., 2009; Pan et al., 2011, 2012; Chen et al., 2013; Feskens et al., 2013; Lee et al., 2013; Abete et al., 2014; Farvid et al., 2015; Etemadi et al., 2017). We find this particularly problematic, as it is not good practice to infer a causal connection to meat eating from such weak and confounded associational data (McAfee et al., 2010; Alexander et al., 2015; Klurfeld, 2015; Feinman, 2018; Leroy et al., 2018b). Moreover, the science used to incorporate the data from meat studies into dietary policy making is all-too often partial and inaccurate (Truswell, 2009). This concern is underlined by the fact that claims from observational epidemiology very often fail to hold up when tested in RCTs (Young & Karr, 2011). Nutritional epidemiology is a useful tool for the generation of hypotheses, but its findings as such do not provide a robust basis for the implementation of health policies in the absence of further substantiation. Or, as stated by Gerstein et al. (2019), "analyses of most observational data from the real world, regardless of their sophistication, can only be viewed as hypothesis generating". This is especially so when the results are counterintuitive, as is the case for meat eating given its long record as an essential food within our species-adapted diet.

3.2. Intervention studies have not been able to indicate unambiguous detrimental effects

As stated by Abete et al. (2014), epidemiological findings on meat eating "should be interpreted with caution due to the high heterogeneity observed in most of the analyses as well as the possibility of residual confounding". The interactions between meat, overall diet, human physiology (including the gut microbiome), and health outcomes are highly intricate. Within this web of complexity, and in contrast to what is commonly stated in the public domain (Leroy et al., 2018a), the current epidemiological and mechanistic data have not been able to demonstrate a consistent causal link between red meat intake and chronic diseases, such as colorectal cancer (Oostindjer et al., 2014; Turner & Lloyd, 2017).

RCTs can play an important role in establishing causal relationships, and generally provide much stronger evidence than that provided by observational data. However, even RCTs are not fail-safe and can also be prone to a range of serious flaws (Krauss, 2018). Intervention studies that overlook the normal dietary context or use non-robust biomarkers should be interpreted with caution, and do not justify claims that there is a clear link between meat and negative health outcomes (see Turner & Lloyd, 2017; Kruger & Zhou, 2018). The available evidence generally suggests that interventions with red meat do not lead to an elevation of *in vivo* oxidative stress and inflammation, which are usually cited as being part of the underlying mechanisms triggering chronic diseases (Mann et al., 1997; Hodgson et al., 2007; Turner et al., 2017). Even in an epidemiological cohort study that was suggestive of an inflammatory response based on an increased CRP level, this effect became non-significant upon adjustment for obesity (Montonen et al., 2013). Moreover, a meta-analysis of RCTs has shown that meat eating does not lead to deterioration of cardiovascular risk markers (O'Connor et al., 2017). The highest category of meat eating even paralleled a potentially beneficial increase in HDL-C level. Whereas plant-based diets indeed seem to lower total cholesterol and LDL-C in intervention studies, they also increase triglyceride levels and decrease HDL-C (Yokoyama et al., 2017), which are now often regarded as superior markers of cardiovascular risk (Jeppesen et al., 2001).

Based on the above, we conclude that there is a lack of robust evidence to confirm an unambiguous mechanistic link between meat eating as part of a healthy diet and the development of Western diseases. It is paramount that the available evidence is graded prior to developing policies and guidelines, making use of quality systems such as GRADE (Grading of Recommendations Assessment, Development and Evaluation; Guyatt et al., 2008). One of the founders of the GRADE system has issued a public warning that the scientific case against red meat by the IARC panel of the WHO has been overstated, doing "the public a disservice" (Guyatt, 2015). The IARC's (2015) claim that red meat is "probably carcinogenic" has never been substantiated. In fact, a risk assessment by Kruger and Zhou (2018) concluded that this is not the case. Such hazard classification systems have been heavily criticized, even by one of the members of the IARC working group on red meat and cancer (Klurfeld, 2018). They are accused of being outmoded and leading to avoidable health scares, public funding of unnecessary research and nutritional programs, loss of beneficial foods, and potentially increased health costs (Boyle et al., 2008; Anonymous, 2016; Boobis et al., 2016).

3.3. A scientific assessment should not overlook conflicting data

Dietary advice that identifies meat as an intrinsic cause of chronic diseases often seems to suffer from cherry-picking (Feinman, 2018). One example of a fact that is typically ignored is that hunter-gatherers are mostly free of cardiometabolic disease although animal products provide the dominant energy source (about two-thirds of caloric intake on average, with some hunter-gatherers obtaining more than 85% of their calories from animal products; Cordain et al., 2000, 2002). In comparison, contemporary Americans obtain only about 30% of calories from animal foods (Rehkamp, 2016).

Whereas per capita consumption of meat has been dropping over the last decades in the US, cardiometabolic diseases such as type-2 diabetes have been rapidly increasing. Although this observation does not resolve the question of causality one way or the other, it should generate some skepticism that meat is the culprit (Feinman, 2018). Moreover, several studies have found either that meat intake has no association with mortality/morbidity, or that meat restriction is association with various *negative* health outcomes (*e.g.*, Key et al., 2009; Burkert et al., 2014; Kwok et al., 2014; Lippi et al., 2015; Hur et al., 2018; Iguacel et al., 2018; Yen et al., 2018). As another example of conflicting information, the epidemiological association pointing to a potential role of the meat nutrient L-carnitine in atherosclerosis via trimethylamine N-oxide (TMAO) formation (Koeth et al., 2013), is contradicted by intervention studies (Samulak et al., 2019) and epidemiological data showing that fish intake, being by orders of magnitude the largest supplier of TMAO (Zhang et al., 1999), improves triglycerides and HDL levels (Alhassan et al., 2017).

Although all of the aforementioned studies—particularly the observational ones—clearly have their limitations, they equally deserve to be incorporated in the scientific analysis and health debates.

4. The nutritional benefits of meat

Throughout human history, meat has delivered a wide range of valuable nutrients that are not always easily obtained (or obtainable) from plant materials (Williams, 2007; McAfee et al., 2010; Pereira & Vicente, 2013; Young et al., 2013; McNeill, 2014; Leroy et al., 2018b). A major asset of meat is of course its high protein value (Burd et al., 2019), with especially lysine, threonine, and methionine being in short supply in plant-derived diets. It brings in B vitamins (with vitamin B12 being restricted to animal sources only), vitamins A, D, and K2 (particularly via organ meats), and various minerals with iron, zinc, and selenium being of particular importance. Also, the long-chain omega-3 fatty acids EPA and DHA present in animal sources are only poorly obtained *in vivo* from α-linolenic acid conversion (Cholewski et al., 2018), making plants a suboptimal source. Despite being overlooked in most nutritional evaluations, meat also contains various bioactive components as taurine (Laidlaw et al., 1988), creatine (Rae et al., 2003; Benton & Donohoe, 2011), carnosine (Everaert et al., 2011), as well as conjugated linoleic acid, carnitine, choline, ubiquinone, and glutathione (Williams, 2007). These components can offer important nutritional benefits, for instance with respect to the optimal development of cognitive functions.

Sufficient intake of animal products is therefore particularly advisable for population groups with enhanced nutritional needs and is helpful to offer nutritional robustness during various stages of life. As such, it contributes to the physical and cognitive development of infants and children (Neumann et al., 2007; Hulett et al., 2014; Tang & Krebs, 2014; Cofnas, 2019) and prevents deficiencies in young females (Fayet et al., 2014; Hall et al., 2017). In the elderly, sufficient meat intake can prevent or improve malnutrition and sarcopenia, also improving health-related quality of life (Pannemans et al., 1998; Shibata, 2001; Phillips, 2012; Rondanelli et al., 2015; Torres et al., 2017).

5. Meat avoidance leads to a loss of nutritional robustness

Diets poor in animal source foods can lead to various nutritional deficiencies, as already described more than a century ago for the case of pellagra (Morabia, 2008), a condition which remains relevant today for poorly planned vegan diets (Ng & Neff, 2018). Advocates of vegetarian/vegan diets usually admit that these diets must indeed be “well-planned” in order to be successful, which involves regular supplementation with nutrients such as B12. However, *realistically*, many people are not diligent about supplementation, and will often dip into deficient or borderline-deficient ranges if they do not obtain nutrients from their regular diet. In such cases, general malnutrition (Ingenbleek & McCully, 2012), poorer health (Burkert et al., 2014), and nutrient limitations (Kim et al., 2018) may be the result, as found in various countries, such as Denmark (Kristensen et al., 2015), Finland (Elorinne et al., 2016), Sweden (Larsson & Johansson, 2002), and Switzerland (Schüpbach et al., 2017). For example, a substantial number of vegetarians and vegans are in the deficient or borderline-deficient range for B12 (Herrmann & Geisel, 2002; Herrmann et al., 2003), despite the fact that the need for B12 supplementation is well-publicized (see also Herbert, 1994; Hokin & Butler, 1999; Donaldson, 2000; Elmadfa & Singer, 2009; Gilsing et al., 2010; Obersby et al., 2013; Pawlak et al. 2013, 2014; Pawlak, 2015; Woo et al., 2014; Naik et al., 2018). B12 deficiency is particularly dangerous during pregnancy (Specker et al., 1988, 1990; Bjørke Monsen et al., 2001; Koebnick et al., 2004), childhood (Rogers et al., 2003) and adolescence (van Dusseldorp et al., 1999; Louwman et al., 2000).

Other potentially challenging micronutrients for people on plant-based diets include (but are not limited to) iodine (Krajcovicová-Kudlácková et al., 2008; Leung et al., 2011; Brantsaeter et al., 2018), iron (Wilson & Ball, 1999;

Wongprachum et al., 2012; Awidi et al., 2018), selenium (Schultz & Leklem, 1983; Kadrabová et al., 1995), and zinc (Foster et al., 2013). Even if plant-based diets contain alpha linolenic acid, this may not (as noted) prevent deficiencies in the long-chain omega-3 fatty acids EPA and DHA (Rosell et al., 2005), which can pose serious risks in pregnancy and for growing children (Burdge et al., 2017; Cofnas, 2019).

Risks of nutritional deficiency are also documented by an extensive list of clinical case reports in the medical literature, with serious and sometimes irreversible pathological symptoms being reported for infants (*e.g.*, Shinwell & Gorodisher, 1982; Zengin et al., 2009; Guez et al., 2012; Bravo et al., 2014; Kocaoglu et al., 2014; Goraya et al., 2015), children (*e.g.*, Colev et al., 2004; Crawford & Say, 2013), adolescents (*e.g.*, Chiron et al., 2001; Licht et al., 2001; O'Gorman et al., 2002), and adults (*e.g.*, Milea et al., 2000; Brocadello et al., 2007; De Rosa et al., 2012; Førland & Lindberg, 2015). The latter reports commonly refer to failure to thrive, hyperparathyroidism, macrocytic anemia, optic and other neuropathies, lethargy, degeneration of the spinal cord, cerebral atrophy, and other serious conditions. Although the direction of causality is not clear, meat avoidance is statistically associated with eating disorders and depression (Zhang et al., 2017; Barthels et al., 2018; Hibbeln et al., 2018; Matta et al., 2018; Nezlek et al., 2018) and may mirror neurological problems (Kapoor et al., 2017).

Our main concern is that avoiding or minimizing meat consumption too strictly may compromise the delivery of nutrients, especially in children and other vulnerable populations. Evidently, health effects of plant-based approaches depend largely on the dietary composition (Satija et al., 2016). Yet, the more restricted the diet and the younger the age, the more this will be a point of attention (Van Winckel et al., 2011). According to Cofnas (2019), however, even realistic vegetarian diets that include diligent supplementation can put children at risk for deficiencies and thereby compromise health in both the short and long term. There is some direct and indirect evidence that the elevated phytoestrogen intake associated with low-meat diets may pose risks for the development of the brain and reproductive system (Cofnas, 2019). Moreover, attempts to introduce dietary modifications that are also compatible with vegan philosophy often pose a medicosocial challenge (Shinwell & Gorodischer, 1982). In our opinion, the official endorsement of diets that avoid animal products as healthy options is posing a risk that policy makers should not be taking. As stated by Giannini et al. (2006): "It is alarming in a developed country to find situations in which a child's health is put at risk by malnutrition, not through economic problems but because of the ideological choices of the parents".

6. Conclusions

Although meat has been a central component of the diet of our lineage for millions of years, some nutrition authorities—who often have close connections to animal rights activists or other forms of ideological vegetarianism, such as Seventh-Day Adventism (Banta et al., 2018)—are promoting the view that meat causes a host of health problems and has no redeeming value. We contend that a large part of the case against meat is based on cherry-picked evidence and low-quality observational studies. The bald claim that red meat is an "unhealthy food" (Willett et al., 2019) is wildly unsupported.

Based on misrepresentations of the state of the science, some organizations are attempting to influence policy makers to take action to reduce meat consumption. Simplification of complex science increases persuasive power but may also serve ideological purposes and lead to scientistic approaches. According to Mayes and Thompson (2015), manifestations of nutritional scientism in the context of biopolitics can have various ethical implications for "individual responsibility and freedom, concerning iatrogenic harm, and for well-being". Well-meaning yet overemphasized and premature recommendations may eventually cause more damage than benefit, not only physiologically but also by unjustifiably holding individuals accountable for their health outcomes. We believe that a large reduction in meat consumption, such as has been advocated by the EAT-Lancet Commission (Willett et al., 2019), could produce serious harm. Meat has long been, and continues to be, a primary source of high-quality nutrition. The theory that it can be replaced with legumes and supplements is mere speculation. While diets high in meat have proved successful over the long history of our species, the benefits of vegetarian diets are far from being established, and its dangers have been largely ignored by those who have endorsed it prematurely on the basis of questionable evidence.

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